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Disturbance effects of roads and fences on the spatial patterns of large mammal dispersal and migration in Amboseli/Tsavo Ecosystem, Kenya

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ABSTRACT

Increasing human populations and changing land-use practices threaten the continued existence of viable populations of large mammals in the Amboseli-Tsavo Ecosystem. These two problems threaten to constrict the wildlife migratory corridor and dispersal areas within three group ranches, Mbirkani, Kimana, and Kuku. This study sought to analyze the status of the migratory corridor and the dispersal area within Kimana Group Ranch. Two major human disturbances, roads and fences, were mapped. The harmonic mean distance of wildlife locations (n =116) from the nearest road within the group ranch was 102.9 m, which was greater than the harmonic mean distance of uniformly distributed random ($t=2.84$, $df=122$, $p < 0.05$). The harmonic mean distance of wildlife from roads was used to create buffers, which resulted in 24.90% of the group ranch under disturbance from roads and fences. Group size was expected to be negatively correlated with average distance from roads and was found to have a weak positive correlation. African elephants (*Loxodonta africana*) were a special focus because of their status as keystone habitat modifier species and their frequent implication in human-wildlife conflicts. In addition to all observations of live elephants, sign (dung, tracks, and vegetation damage) were also recorded. Three high concentrations of elephants were found, one a result of contraction of the migration corridor between the two fences. The fences were found to have substantial human-inflicted damage and the larger of the two was not electrified. Observability was an issue because habitat, body size, and group size all influence the probability of detection. Local people are settling outside of the fences, fence electricity is not maintained, and local people often undermine the integrity of the fence by damaging it. Factors not examined in this study likely have strong influences on the spatial distribution of wildlife in Kimana group ranch. Additional factors possibly affecting wildlife movement patterns include habitat, water sources, homesteads, and livestock. Future studies will incorporate habitat, water, homesteads, and livestock mapping within Kimana group ranch, the use of aircraft could provide more accurate wildlife locations.

Key Words: African elephant, displacement of wildlife, Kenya, Kimana group ranch, migration corridor, road ecology, Tsavo-Amboseli ecosystem, wildlife conservation

INTRODUCTION

Amboseli/Tsavo Ecosystem

The Amboseli/Tsavo Ecosystem is one of the last remaining wildlife conservation areas in Kenya (Wishitemi and Okello 2003). Two areas comprise this ecosystem: the Tsavo West National Park, which functions as the wet season habitat, and the Amboseli Game Reserve, which functions as the dry season habitat (Okello 2005). The Maasai group ranches, Kuku, Kimana, and Mbirkani, lie between these two areas and function as a migratory corridor and dispersal area for the ecosystem (Wishitemi and Okello 2003). Corridors can ease the threats to biodiversity because they are important migration routes and provide access to otherwise unavailable resources (Newmark 1996; Meffe and Carroll 1997).

The Maasai, a pastoralist society, have historically coexisted with wildlife for hundreds of years, and pastoralists in general have coexisted with wildlife for around 2500 years in East Africa (McCabe 1992). Yet Kenya's human population in the last few decades has been increasing at about three percent per year (Wishitemi and Okello 2003). This poses conservation challenges even with the traditional Maasai pastoralism. As the human population increases, humans and wildlife will increasingly compete for space and water. Cattle are much more water dependent than most of the wildlife species found in the area which only heightens the competition between humans and wildlife (Owen-Smith 1999).

The group ranches between Amboseli and Tsavo are slowly changing from their original design of communal pastoralism to privately owned agriculture. The reasons behind this change vary from changing culture to human population increases. Originally, group ranch membership rights excluded younger people and women and were vested only in the male elders (Campbell *et al.* 2000). Currently the Maasai are seeking to subdivide their group ranches in their quest towards individual land ownership (Okello *et al.* 2003). This idea is particularly popular with young, educated members of the group ranches, who see no other way to establish respect in the community and acquire monetary wealth (Okello *et al.* 2003). The subdivision of land will lead to increased fragmentation, as smaller individual plots of land are fenced (Boone and Hobbs 2004). While recognizing the potential negative effects of land sub-division on pastoralism and wildlife, most Maasai still support subdivision (Okello *et al.* 2003). The Maasai, in the face of the booming population in the region, are leasing and selling their land to emigrants who quickly embrace agricultural practices (Campbell *et al.* 2000). This increase in agriculture is detrimental to conservation, as intensive agriculture and protected areas do not make good neighbors (MacKinnon 1986). Over 89% of the local communities in the Amboseli-Tsavo Ecosystem now practice pastoralism and agriculture, and only 9% continue to practice solely pastoralism (Wishitemi & Okello 2003).

The changing land use not only threatens to fragment the ecosystem and insularize the parks, but it pushes another issue to the forefront. While inside the designated conservation areas, the wildlife are generally protected. However, during annual migrations outside the boundaries of these areas they become vulnerable to conflicts with humans (Seno and Shaw 2002). Human-wildlife conflict will increase as human presence becomes more prevalent in the group ranches. Local communities view wildlife as a threat to their livestock through competition, predation, and the transmission of diseases (Ngethe *et al.* 1994). Migrating wildlife also pose a significant risk to agriculture. The promise of high-energy food sources draws wildlife to crops and they can destroy or eat an entire field in one night. This leads to explosive situations, in which individuals and families can lose their entire livelihood in one night.

African Elephants

One species, the African elephant (*Loxodonta africana*), is particularly destructive and dangerous to humans. Elephants attracted to agriculture will alter their migration patterns in order to utilize the nutrient-rich food sources throughout the year (Ekobo 1997). Of the 230 people killed by wildlife between 1989 and 1994, 39 percent were due to elephants (Sindiga 1999). Elephants as a migratory species extensively use the dispersal area around Amboseli. The elephant numbers have declined from 1.3 million in 1979 to 625,000 in 1989 due to poaching. Elephants numbers within the Amboseli/Tsavo Ecosystem were around 1,000 in the 1960s, then decreased to 350 during the 1970s and 1980s due to poaching; now their numbers have rebounded to around 1,300 (Western personal communication 2004).

Elephants are essential to creating new habitats; by knocking down trees they create new grasslands, which diversify and increase the size of the savannah ecosystem (Waithaka 1996). The loss of elephants would likely lead to biological impoverishment and accelerated extinction of other species (Poole and Thomsen 1989). However, elephants can pose a threat if they are insularized inside small areas such as parks; their ecological services soon overwhelm the environment, which results in destroying the environment (Western personal communication 2004). Two communities within Kimana group ranch (Kimana and Namelok) built electric fences around their towns to protect their crops and water sources from elephants (Boone and Coughenour 2001).

Road Ecology

There is overwhelming evidence indicating roads directly displace individuals, reduce the amount of suitable habitat, and alter the behavior and habitat use patterns of wildlife (Lyon 1984). In the U.S. elk (*Cervus elaphus*) have been shown to actively avoid roads, 0.2 km from primitive roads in southwestern Washington (Perry and Overly 1976), 1 km in Montana (Lyon 1979), and 0.2 km during the winter in Colorado (Rost and Bailey 1979). Vistnes *et al*. 2004, found that roads in conjunction with power lines acted as barriers to wild reindeer (*Rangifer tarandus*) migration in Norway. Active avoidance of roads leads to reduced home ranges and more stress during migrations. Caribou (*Rangifer tarandus*) in northeastern Alberta crossed roads on average six times fewer than expected (Dyer *et al.* 2002).

Previous Studies within Amboseli/Tsavo West Ecosystem

The aim of this research was to examine the wildlife corridor and dispersal area between Amboseli National Reserve and Tsavo West National Park, in particular the Kimana group ranch. Previous studies have examined the Kuku group ranch's corridor size and status, as well as the human activities and the resulting wildlife displacement (Berg 2003; Gooch 2004 and Hale 2004). These studies demonstrated that different human activities had varying displacement impacts. The activities studied include agricultural, residential, institutional, roads, and livestock. The total area taken by human structures and activities in the Kuku group ranch was 234.2 km^2 (24.40%), leaving the remaining area, 75.6% available for wildlife (Hale 2004). Within the Kuku group ranch, spatially there were two human clusters growing together and cutting off the corridor from Kimana Wildlife Sanctuary, within the Kimana group ranch to Tsavo West National Park (Hale 2004).

Objectives

The specific objectives of this study were:

i) To map and visually display the contraction of the dispersal area and migration corridor within Kimana group ranch

ii) To determine interspecific spatial patterns in relation to roads of large migratory mammals within Kimana group ranch

iii) To examine spatial patterns in wildlife migration and dispersal within the Kimana group ranch with particular attention to African elephants (*Loxodonta africana*)

METHODS

Study Area

Kimana group ranch is located within the Loitoktok Division of the Kajiado District, Kenya with Amboseli to the east and Tsavo West to the west (Fig. 1). The total area of the Loitoktok division is 6,090 km^2. The topography of the district is composed of plains and some volcanic hills. The Loitoktok division receives the highest annual rainfall in the entire Kajiado District with an average of 1,250 mm per year. Specifically, the Kimana group ranch has a bimodal rainfall pattern significantly influenced by its high altitude and proximity to Mt. Kilimanjaro. It receives 30 percent of its annual rainfall during the short rains (October - December) and 45 percent during the long rains (March-May). However, this does not take into account the prolonged droughts that frequently plague this arid region. The temperature within the Loitoktok division ranges from 30 - 10 C°. The coolest period is during July and August while the hottest period occurs between November and April (Berger 1993). The Kimana group ranch has an area of 297.9 km^2 with 168 registered members. The density of the members within the Kimana group ranch is 1.77 km^2 per member. Amboseli National Reserve is 392 km^2 and Tsavo West National Park is 9,056 km^2 (Sindiga 1995). These two vastly different parks encompass one ecosystem: the Amboseli-Tsavo Ecosystem, the Kimana group ranch is used both as a foraging area and as a migration corridor for wildlife.

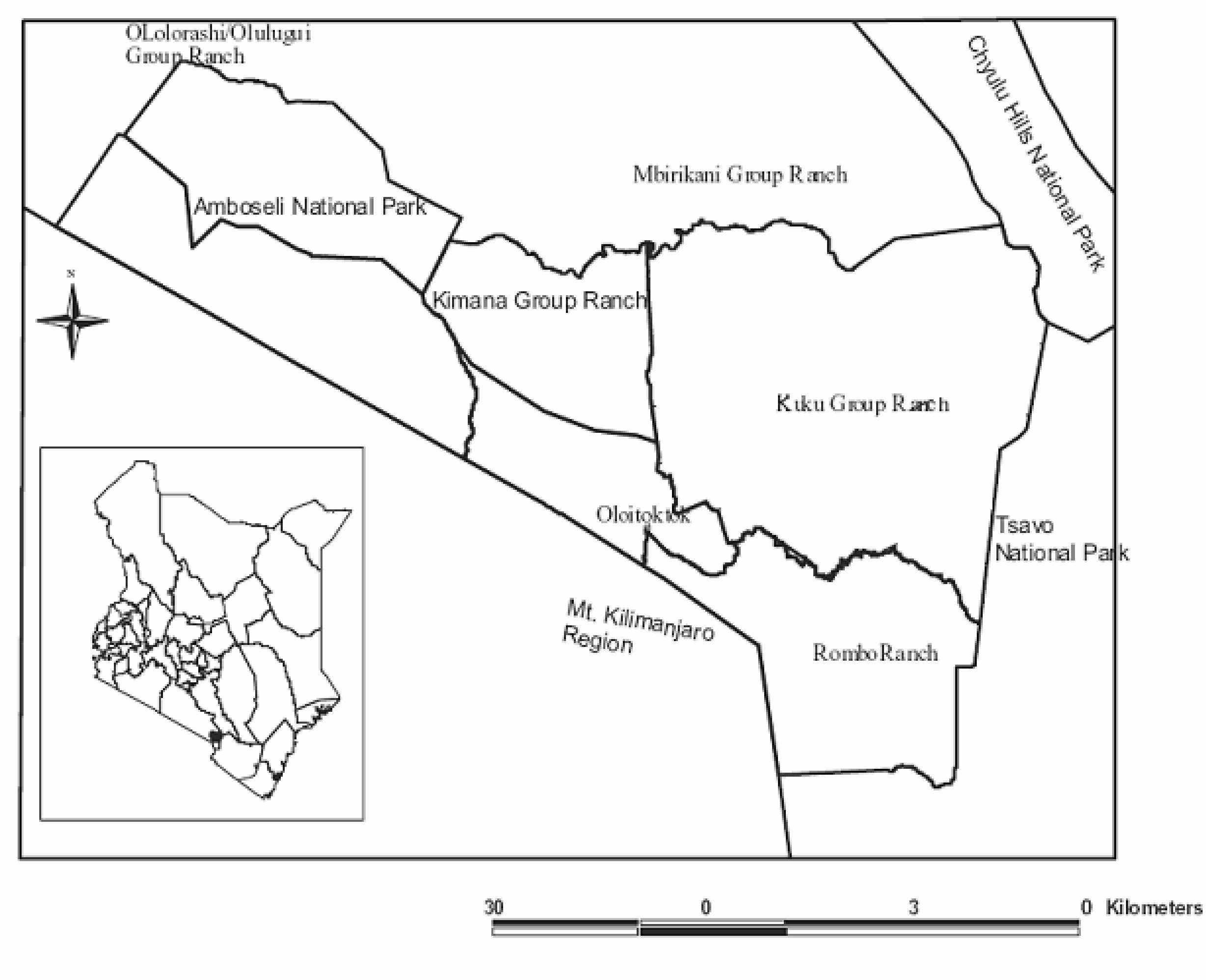

Figure 1. Southcentral Kenya, including the Kimana group ranch, Amboseli National Reserve to the west and Tsavo West National Park to the east, this figure was modified from Okello 2005.

Roads and Fences

All roads were mapped using Global Positioning System (GPS) readings taken every km on main roads, every 0.5 km on all other roads, and at midpoint of any major curve in the road (less than approx. 158°). At each point where a location was recorded, road width was estimated. Estimated width included the road, drainage ditches, and any immediately adjacent footpaths (within 1 m of roadway). All points were mapped using ArcView software and lines were drawn between points to represent the road network. Length and the average width of each road was used to estimate the total area of the road.

The circumference and area of the Kimana and Namelok electric fences were determined by recording GPS points at every corner. At gates, a GPS point was recorded in the middle and the width of the opening was recorded. All points were mapped using ArcView software and lines were drawn between points to represent the fence boundaries. At every point where the fence had some form of damage a GPS reading was taken and the damage type (missing posts, loose wires, disconnected wires, cut wires, wires tied or twisted together, wires held down by rocks) was recorded. The number of solar powerhouses for each fence was recorded as well as their current operational status and a GPS point was recorded at each location.

Wildlife

Wildlife surveys were conducted from November 18th, 2004 to November 26th, 2004, from 8:00am till 4:00pm while driving approximately 10mph. The entire Kimana group ranch road system was sampled and all mammals larger than, or equal to, the size of a Kirk's dik-dik (*Madoqua kirkii*) and all primates sighted were recorded using approximately 1 km transects (500 m on each side of the road). Wildlife was recorded opportunistically off-road when the terrain allowed. The species, number of individuals, GPS point, habitat type, and time of sighting were recorded. From the GPS point, the distance to any visible human disturbances were recorded. Special attention was given to recording the presence of elephants, GPS points were recorded at every sighting of elephant sign (dung, tracks, or vegetation damage) in addition to every live sighting. All GPS points were mapped using ArcView software and labeled according to species and group size.

Analysis

Uniform randomly distributed points (n=221) were created using ArcView, the distance to the nearest road of each point was also measured using ArcView. These points were used as the control, representing the locations of wildlife under no selective pressures in Kimama group ranch. These points were more likely to be found inside fences than wildlife ($\chi^2 = 14.52$, df = 1, $p < 0.05$). Using this as justification all points within the fences were removed from the study wildlife (n=24) and random (n=46). It was assumed that wildlife could be accurately identified at a maximum distance of 500 m. Wildlife were occasionally observed in open bush country but the terrain did not allow for equal or adequate coverage beyond the developed and undeveloped roads. Thus all points beyond 500m from the nearest road were removed from the study, wildlife (n=81) and random (n=113, Fig. 2). Harmonic mean was used when averaging the distances from roads because it places more emphasis on smaller numbers, which in this study are more accurate than larger numbers. In other words, the difference between 20 m and 30m is more important than the difference between 450 m and 460 m, using harmonic mean assures that this stress is maintained. To determine if roads affect the locations of wildlife a t-test was used with the null hypothesis that the average distance of wildlife points from the nearest road (U_0) is equal to the average distance of random points from the nearest road(U_x), H_0: $U_0 = U_x$. Alternate hypotheses' were, H_{a1}: $U_0 > U_x$ and H_{a2}: $U_0 < U_x$. When testing individual species against the

Figure 2. Maps of Kimana group ranch showing all wildlife observations (a), then all wildlife observations used in analysis (b) and all uniformly distributed random points (c), then all random points used in analysis (d). Data collected in Kimana group ranch, Kenya during November 2004, uniformly distributed random points created using ArcView, November 2006.

null hypothesis only species with ten or more observations were used. To compare group size and average distance from roads a linear regression equation was used with average distance from roads as the independent variable and average group size of a species as a dependent variable.

RESULTS

Sixteen species were observed in Kimana group ranch during the study. After both treatments of the data six species had at least 10 observations, giraffe (*Giraffa camelopardalis*, n = 18), Grant's gazelle *(Gazella granti*, n = 20), impala (*Aepyceros melampus*, n = 10), Kirk's dik-dik (n = 12), plains zebra (*Eqqus quagga*, n = 19), and Thomson's gazelle (*Gazella Thomsoni*, n = 15, Table 1).

Fence and Road effect analysis

The difference between the expected number of wildlife within the two fences and the actual number of wildlife groups inside the fences was significant ($\chi^2 = 14.52$, df = 1, $p < 0.05$). The harmonic mean of the distances from roads of the random points (n=62) was 81.34 ± 6.17m (Fig. 3). The harmonic mean of the distances from roads of wildlife points (n=116) was 102.87 ± 4.40m. Kirk's dik-dik's (n=12) harmonic mean was 53.19 ± 5.98m. Grants gazelle's (n=20) harmonic mean was 126.71 ± 14.21m. Giraffe's (m=18) harmonic mean was 132.35 ± 44.77m. Impala's (n=10) harmonic mean was 157.99 ± 62.10m. Thomson's gazelle's (n=15) harmonic mean was 121.90 ± 29.01m. Plains zebra's (n=19) harmonic mean was 81.37 ± 11.61m.

There was a significant difference between wildlife and random points ($t = 2.84$, df = 122, $p < 0.05$). Grant's gazelle had a significantly greater distance from the roads than random points 126.7 ± 14.2m ($t = 2.93$, df = 27, $p < 0.05$) while Kirk's dik-dik had a significantly smaller

Table 1. All wildlife observations recorded during study in Kimana group ranch, Kenya during November 2004. Censor 1 refers to the observations left after the removal of wildlife and random points within the Kimana and Namelok fences. Censor 2 refers to the observations left after the removal of wildlife and random points greater than 500 m from the nearest road.

Species	**All observations**	**Censor 1**	**Censor 2**
African elephant (*Loxodonta africana*)	7	6	4
Bat-eared fox (*Otocyon megalotis*)	1	0	0
Black-backed jackal (*Canis mesomelas*)	1	1	0
Common eland (*Taurotragus oryx*)	6	6	2
Gerenuk (*Litocranius walleri*)	3	3	0
Giraffe (*Giraffa camelopardalis*)	31	31	18
Grant's gazelle (*Gazella granti*)	38	37	20
Impala (*Aepyceros melampus*)	23	19	10
Kirk's dik-dik (*Madoqua kirkii*)	20	15	12
Lesser kudu (*Tragelaphus imberbis*)	3	3	2
Plains zebra (*Equus quagga*)	37	32	19
Syke's monkey (*Cercopithecus albogularis*)	1	0	0
Thomson's gazelle (*Gazella thomsoni*)	25	24	15
Vervet monkey (*Chlorocebus aethiops*)	17	13	7
Waterbuck (*Kobus ellipsiprymnus*)	1	1	1
Yellow baboon (*Papio cynocephalus*)	7	6	6
Random Points	221	175	62
Total Wildlife	221	197	116

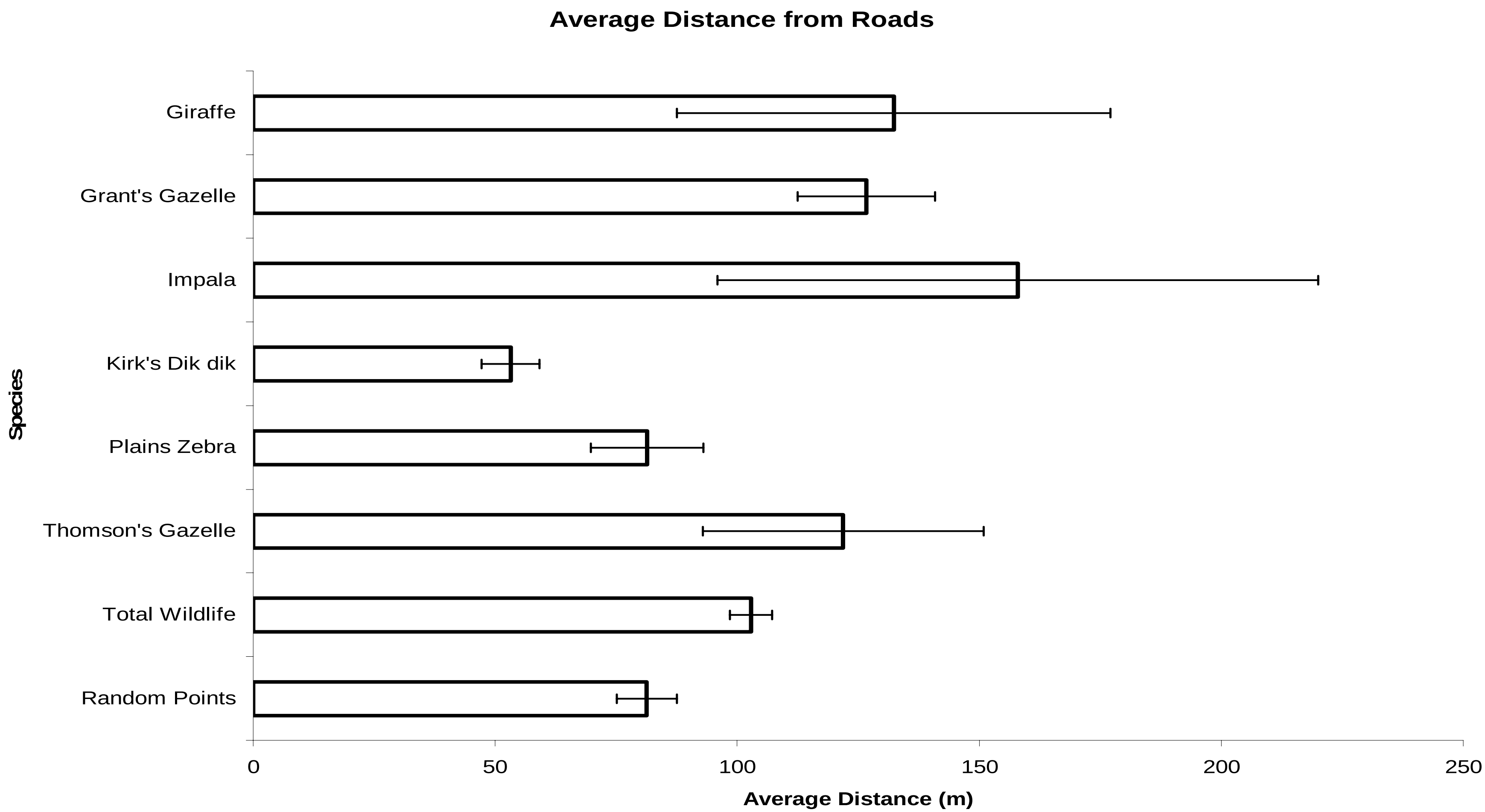

Figure 3. Comparison of the harmonic mean distance from roads of wildlife species and uniformly distributed random points within Kimana group ranch, Kenya from data collected November 2004.

distance from roads than random points 53.2 ± 6.0m ($t= 3.27$, $df=39$, $p < 0.05$). Giraffe, impala, plains zebra, and Thomson's gazelle failed to reject the null hypothesis.

The combined area of all the roads in Kimana group ranch is 1.70 km^2. The addition of 102.9 m buffer on both sides of the road, accounting for overlap, the total area of roads and their buffer zones is 38.63 km^2. Excluding the roads within the fences the total area with buffers is 21.21 km^2, which is 7.12% of the group ranch. The area of the Kimana fence is 42.39 km^2 and the Namelok fence has a total area of 18.11 km^2 of which 10.59 km^2 is within Kimana Group Ranch. The total area fenced off within Kimana group ranch is 52.98 km^2, which is 17.78% of the group ranch (Fig. 4). The total displacement of the fence and buffered roads is 74.19 km^2, which is 24.90% of the group ranch. Several species occurred within the fences, Thomson's gazelle and one bat-eared fox (*Otocyon megalotis*) occurred within the Namelok fence, while the African elephant, impala, Kirk's dik-dik, plains zebra, Syke's monkey (*Cercopithecus albogularis*), vervet monkey (*Chlorocebus aethiops*), and yellow baboon (*Papio cynocephalus*) all occurred within the depowered Kimana fence.

The perimeter of the Kimana fence was 34.51 km and it had 249 incidents of damage, approximately one incident every 139 m. The still powered Namelok fence perimeter was 21.15 km with 22 incidents of damage, approximately one incident every 961 m. The main type of damage on the Kimana fence was to the barbed wire ($n =101$) followed by missing poles ($n =61$), while the most frequent damage recorded on the Namelok fence was live wire twisted or held down by a rock ($n=14$) followed by live wire disconnected ($n = 5$, Table 2).

The average group size of all wildlife species was 5.15 ± 0.31. The species with the largest average group size was Plains zebra at 6.79 ± 0.60, followed by impala at 6.32 ± 1.23,

Table 2. Frequency of damage by category recorded on Kimana and Namelok electric fences within Kimana group ranch, Kenya during November 18 – 19, 2004.

Kimana Electric Fence

Damage Type	Frequency of Damage
Barbed wire	101
Poles missing	61
Live wire loose/disconnected	41
Live wire twisted/rock	30
Live wire cut	16
Total Damage	**249**

Namelok Electric Fence

Damage Type	Frequency of Damage
Live wire twisted/ rock	14
Live loose/disconnected	5
Live wire cut	2
Barbed wire	1
Poles missing	0
Total Damage	**22**

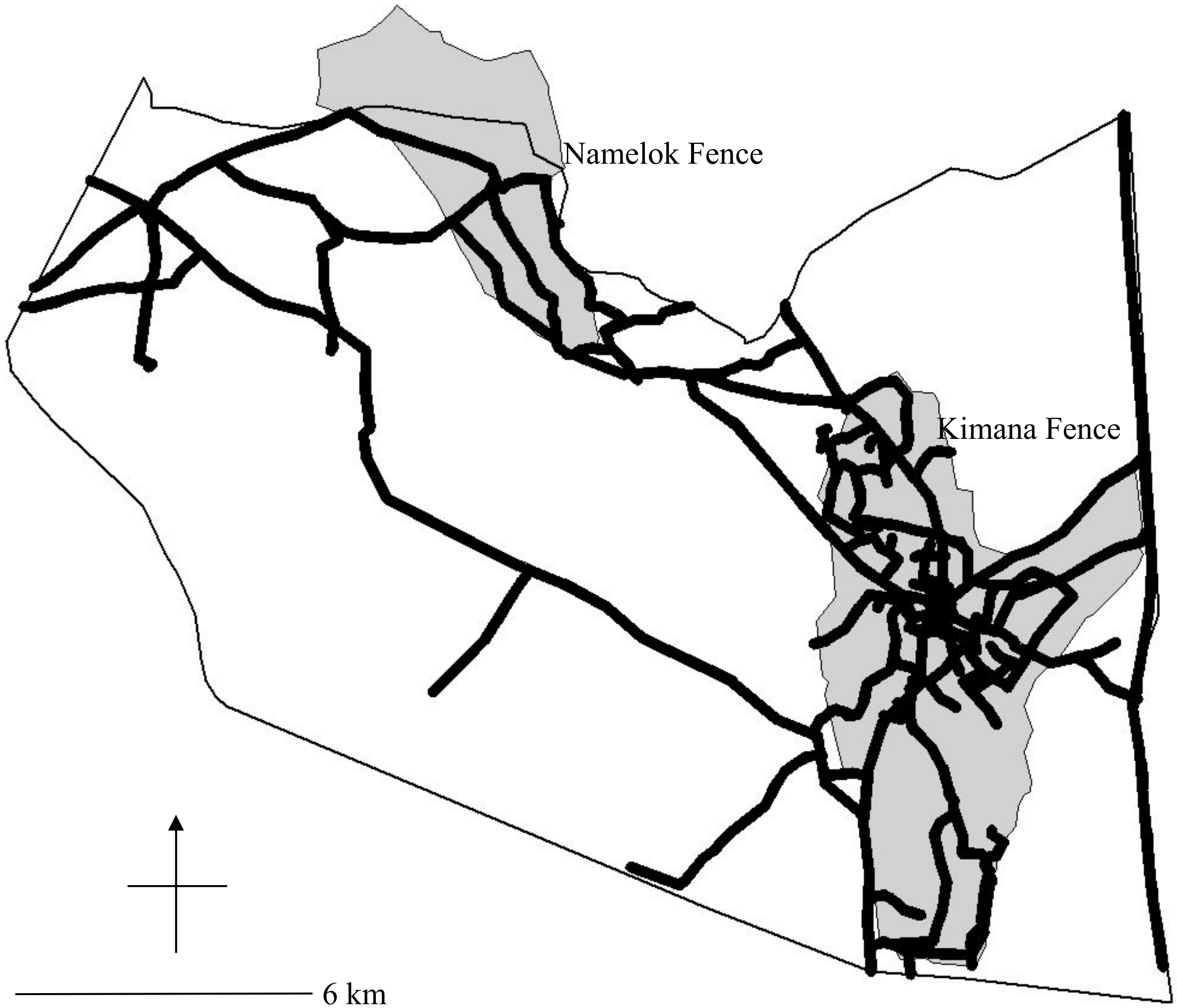

Figure 4. Map of Kimana group ranch, Kenya showing Namelok (north central) and Kimana (eastern) fences in gray. Roads and 102.9m buffer zone are also shown in black. Data collected during November 2004.

then Grant's gazelle at 5.95 ± 0.87. The other three species had average group sizes smaller than the total average, giraffe at 4.21 ± 0.54, followed by Thomson's gazelle with 2.32 ± 0.35, and then Kirk's dik-dik at 1.61 ± 0.14. A positive linear relationship was observed between group size and distance from nearest road, with the equation, $y = 0.0236x + 2.0086$ and $R^2 = 0.168$ (Fig. 5).

Species Distribution

The six species seemed to have slight differences in their distribution and migration pattern within the group ranch. Thomson's gazelle appeared to be focused more in the northern portion of the group ranch (Fig. 6). Giraffe (Fig. 7), Grant's gazelle (Fig. 8), and plains zebra (Fig. 9) seemed to be more centrally located. The impala was more focused in the eastern portion of the group ranch (Fig. 10) and Kirk's dik-dik was more focused in the southeastern part (Fig. 11).

Elephant observations, tracks, dung, and signs of damage had three concentrated areas, one west of the Namelok fence, one between the Namelok and Kimana fences, and one northeast of the Kimana fence (Fig. 12). Elephants and their sign were observed within the unelectrified Kimana fence but not within the electrified Namelok fence.

DISCUSSION

The Kimana group ranch serves as an important corridor for the migration of large mammals between Amboseli National Reserve and Tsavo West National Park (Wishitemi and Okello 2003). Two major barriers to migration in Kimana group ranch are fences and roads. The two electric fences encompass a significant percent (17.78%) of the group ranch. The

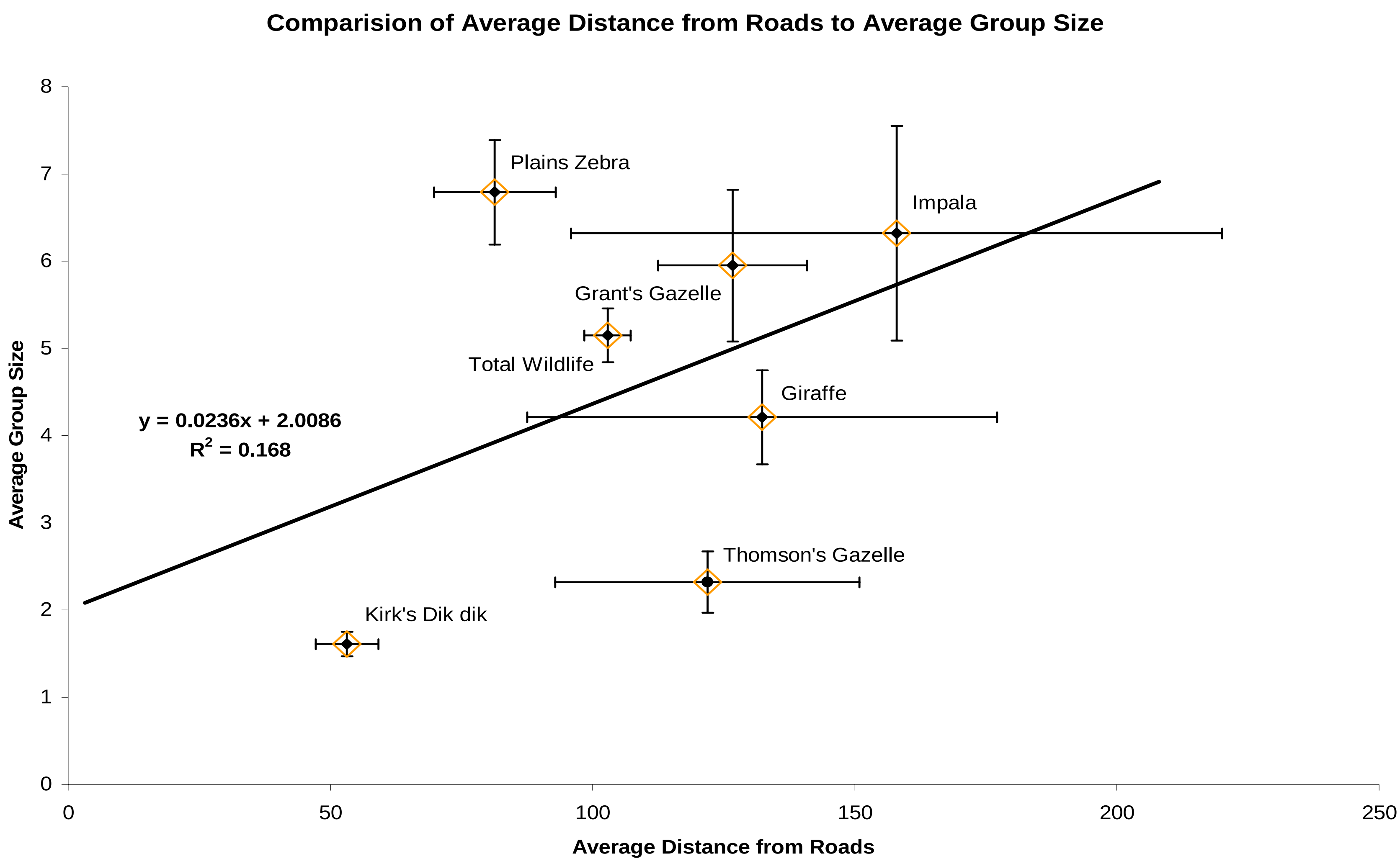

Figure 5. Comparison of average distance from roads (x ± SE) to average group size (x ± SE) of six species' of large mammals in Kimana group ranch, data collected November 2004.

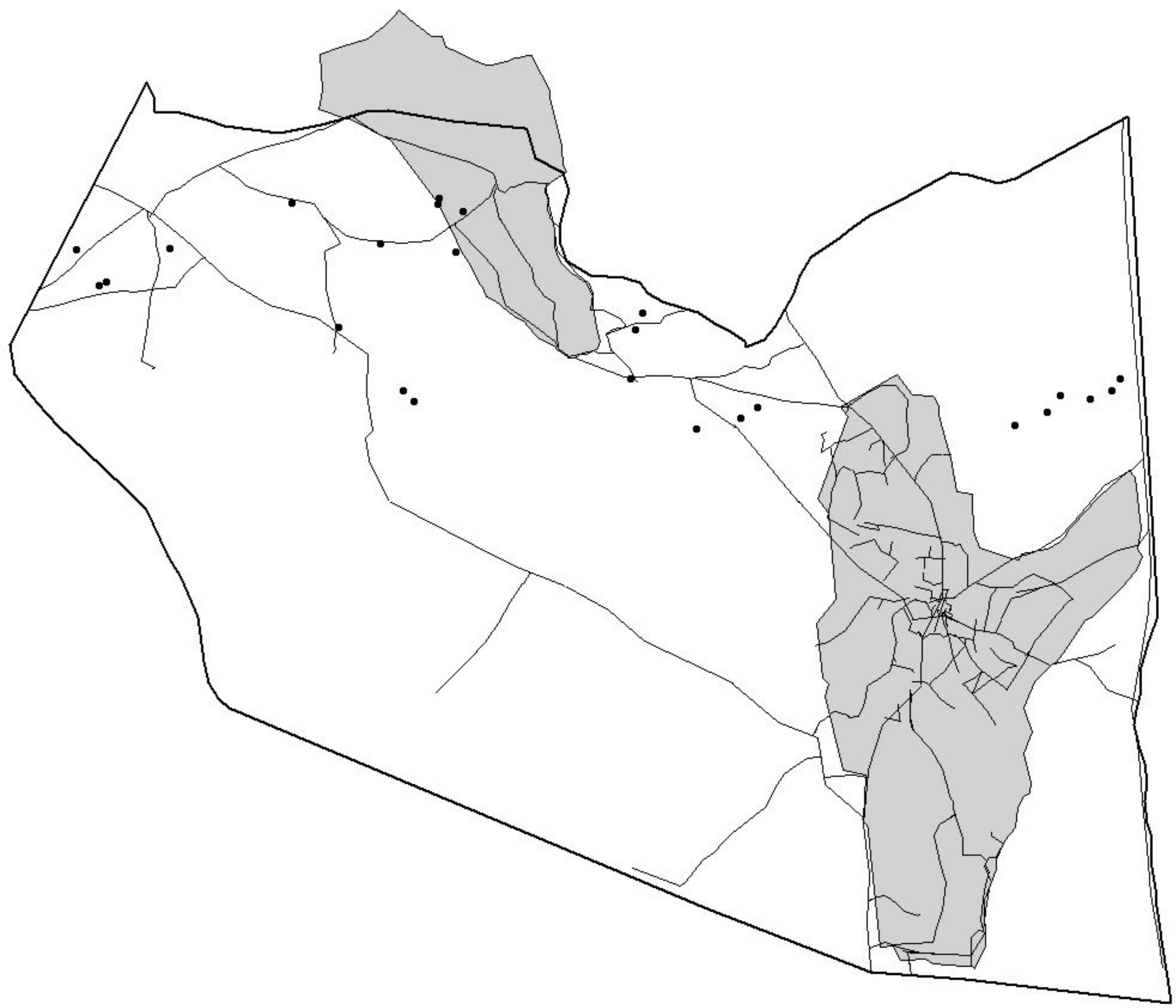

Figure 6. Thomson's gazelle (*Gazella thomsoni*) distribution within Kimana group ranch, Kenya during November 2004.

Figure 7. Giraffe (*Giraffa camelopardalis*) distribution within Kimana group ranch, Kenya during November 2004.

Figure 8. Grant's gazelle (*Gazella granti*) distribution within Kimana group, Kenay ranch during November 2004.

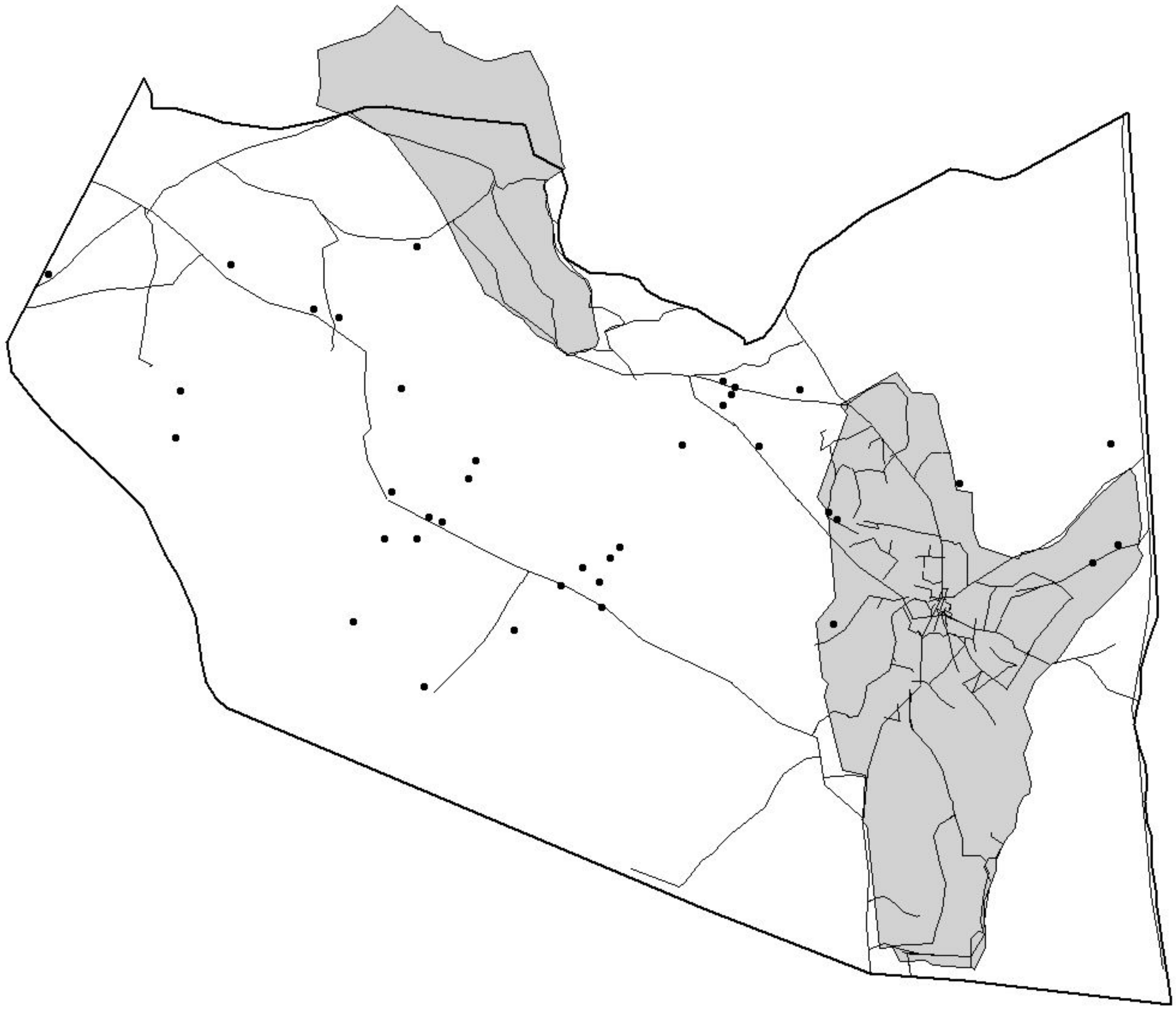

Figure 9. Plains zebra (*Equus quagga*) distribution within Kimana group ranch, Kenya during November 2004.

Figure 10. Impala (*Aepyceros melampus*) distribution within Kimana group ranch, Kenya during November 2004.

Figure 11. Kirk's dik dik (*Madoqua kirkii*) distribution in Kimana group ranch, Kenya during November 2004.

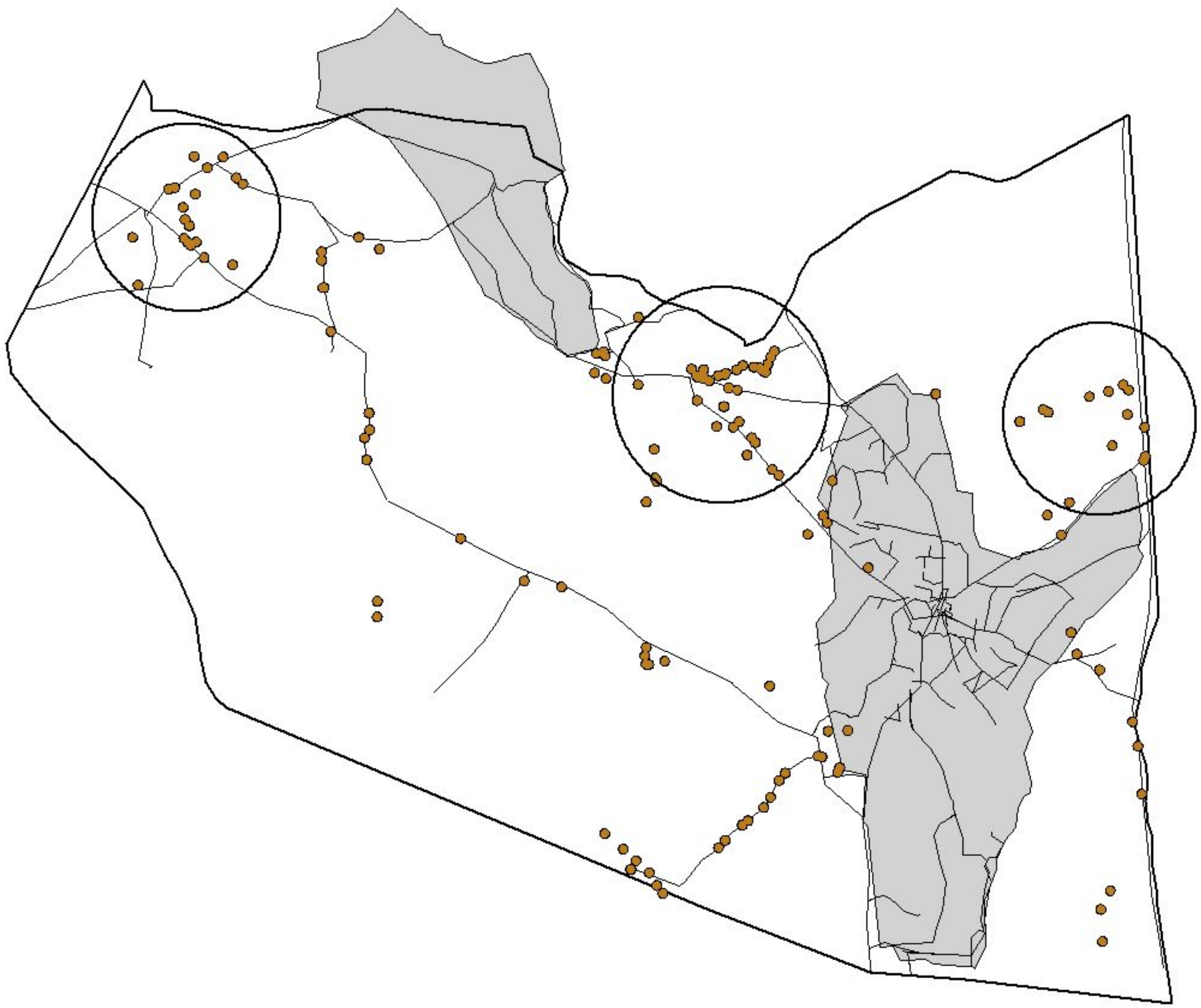

Figure 12. African elephant (*Loxodonta africana*)) distribution and location of sign observed within Kimana group, Kenya during November 2004. Three rings are drawn around areas of highest concentration.

Namelok fence is still powered but the Kimana fence is no longer powered, while both fences are effective at preventing wildlife from entering. The effectiveness of the Kimana fence could be waning, given that large herbivores like the plains zebra, impala, and even African elephants were observed within the fence. The original purpose of the fence was to reduce human-wildlife conflict, but in the fence's current state wildlife will only increase their presence within the fence resulting in increased human-wildlife conflict. Regardless, both fences are still a barrier restricting the corridor east west through the group ranch to approximately 5.15 km. The fence's negative effect is compounded by the presence of an extensive road system.

The road system within Kimana group ranch covers approximately 1.70 km^2. Wildlife actively avoid roads, the road effect adds 102.9 m buffer zone around the roads, which increases the road area outside of the fences to 21.21 km^2, and this encompasses an additional 7.12% of the group ranch. Some wildlife species seemed to have higher than average avoidance of roads including, Grant's gazelle, giraffe, impala, and Thomson's gazelle. Kirk's dik-dik and plains zebra had a lower than average avoidance of roads. Kirk's dik-dik's road avoidance might have been underestimated, it's small size (55-77 cm) and it's preference for dense high brush both decrease it's observability, which could make it appear to be relatively undisturbed by roads (Kingdon 1997). When Kirk's dik-dik, vervet monkey, and savanna baboon are removed from the analysis the average distance increases by 50%. This though is simply speculation and without evidence that these species were truly underestimated, they must be included in the analysis.

Distance from roads appears to increase as group size increases, which is contrary to the prediction that increased group size will decrease distance from roads. A larger group conveys a stronger sense of security, because of the effect of collective wariness. The differing results could also be tied to observability; larger groups could simply be observed at greater distances than smaller groups, thus biasing larger groups to have greater distances from roads.

Species' movement patterns through the group ranch appear to have differences with other species but due to low sample sizes no relation to the presence of roads or fences can be elucidated. Species migrational patterns were likely linked to habitat type; at the time of this study, habitat and vegetation data was not available for this area, thus further inferences cannot be made in relation to differing dispersal patterns. One species distribution in particular though, the African elephant, warrants a closer look. Elephant sightings and sign occur throughout the group ranch but are concentrated in three areas; these areas suggest a movement pattern through the northern region of the group ranch, which bottlenecks between the two fences. These areas of higher elephant concentration and in particular the bottleneck pose a significant threat to both crops and local farmers attempting to defend crops. These three areas likely have high rates of human-wildlife conflict, which will only increase as roads and settlements push beyond the fences.

Several species, mainly of the family Carnivora are known to be in the area but because most of these species are active only at night their presence was not detected in this study. Locals gave reports of lions (*Panthera leo*) within the group ranch and striped hyenas (*Hyaena hyaena*) were heard regularly at night. These species are important components to the ecosystem and the tourism capabilities of the region. Carnivores are often implicated in losses of livestock thus they are crucial factors in human-wildlife conflict.

Management Implications

Kimana group ranch, as a wildlife dispersal and migration corridor, is under stress from human encroachment, this study examined the fence and road component of human encroachment. Other factors of human encroachment also threaten the stability of the corridor, new human settlements, expanding livestock herds, expanding agricultural practices, and the divergence of water to benefit humans, livestock, and agriculture. Further studies on the effect of these factors are essential for a more complete understanding of the delicate system. The recent creation of a community wildlife reserve in the northeastern section of the Kimana group ranch is important for local wildlife. It helps protect the integrity of the corridor and serves as a stopping point and refuge for wildlife. The wildlife reserve also functions as means to involve the local community in conservation and access to the lucrative business of ecotourism.

The Kimana fence should be repowered and maintained in the future, so that human-wildlife conflict can be minimized. Repowering of fence would serve two purposes, it would reinvigorate avoidance behavior, which reduces wildlife intrusions and reduces damage done by locals. The high frequency of damage to the Kimana fence is extremely detrimental to its integrity as a wildlife barrier, the fence should be properly maintained and any future major damages should be reported to local group ranch authorities. New settlements outside of the fence should be discouraged, as the fence not only protects humans from wildlife but also wildlife from humans.

Habitat types should be mapped across the Kimana group ranch as this factor undoubtedly influences wildlife dispersal and the quality of the migration corridor. A problem in this study was the incomplete coverage of the group ranch, due to safety and access issues. In the future, similar studies would benefit from the use of aircraft to deliver more complete, accurate, and compelling data. Access to the Kimana Wildlife Sanctuary would allow for comparisons between wildlife without disturbance from human structures and activities and wildlife outside its borders which are subject to an increasingly human-dominated landscape. This would enhance the knowledge of this system and improve management suggestions.

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